NRAC/TAGIS Collaboration Build Coal Fields LiDAR Data:

West Virginia Coal Field Watersheds NRAC LiDAR Collection Flights and TAGIS In-house Derived Data Production

LiDAR, an acronym for Light Detection And Ranging, refers to a notably dense and accurate remote sensing technique for calculating elevation values. Aerial LiDAR is referred to as being "flown;" the method utilizes aircraft from which expensive, highly specialized scanners rapidly emit invisible infrared energy pulses that strike surfaces at or near the ground. The pulses are reflected back to the aircraft and then measured in a fashion similar to radar. The dataset produced, commonly known as a point cloud, can be used to create detailed 3-dimensional representations of vast areas of our planet.

LiDAR data possesses a number of inherent advantages as a remote sensing technique and is thus employed globally by governmental agencies covering a broad range of societal responsibilities. Perhaps the most remarkable of these advantages is the potential of LiDAR to produce extremely resolute elevation data with vertical accuracy in the range of 15-30 centimeters, depending on the selected flying height and type of scanner utilized. In the time it takes to survey less than a dozen spot elevations using geodetic-quality GPS hardware accurate to a few millimeters, an aircraft equipped with a LiDAR scanner can collect millions of centimeter accurate measurements to paint huge geographic areas. Additionally advantageous, for every emitted pulse of energy, the LiDAR scanner's sensor can measure multiple returns, vastly improving the emitted energy's chance of penetrating tree canopy in forested areas. LiDAR is, therefore, also used to map aboveground features like building shapes and the position of infrastructure such as high voltage power transmission lines.

Raw binary LiDAR (.LAS) files are usually delivered as tiles measuring "x" meters by "y" meters; with specialized LiDAR software geospatial professionals develop these tiles into derived data products more readily utilized by the general public and geospatial professionals alike. LiDAR files are generated into products such as an intensity image, breaklines (boundaries along water bodies), a digital elevation model (DEM) of terrain flown, an elevation grid, slope and aspect datasets, building footprints, vegetation canopy height, the contours favored by engineers to represented elevation and, most notably, a stunningly detailed hillshade dataset.

So far, WVDEP, a few individual counties in the State, the US Army Corps of Engineers' Huntington District and FEMA have funded collection of LiDAR over an estimated 50 percent of West Virginia's terrain. Until spring of 2012, however, no cooperative attempt had been made in West Virginia to combine existing LiDAR datasets owned by federal, state and county governments or to make a united dataset easily accessible by contributing parties. However, the potential uses of this technology and data products for the state of West Virginia are enormous.

In 2003, the West Virginia State Addressing and Mapping Board (WVSAMB) created the first aerial photography-based elevation dataset of all 24,038 square miles of the State. At the time, it was considered one of the best statewide elevation datasets in the country. That same year, WVDEP first utilized LiDAR data in the aftermath of heavy storm events that produced devastating flooding in several southern West Virginia watersheds. This first West Virginia State government LiDAR collection by the Division of Mining and Reclamation (DMR) provided important information in WVDEP's environmental investigations. After mapping impacted watersheds both with and without mining, the resulting data was utilized to create hydrologic models comparing scenarios about the intensity of the flooding. The LiDAR dataset

served as key evidence in refuting allegations that mining significantly increased that summer's flooding. In contrast to WVSAMB's elevation dataset, LiDAR is far more accurate and provides greater resolution for better depiction of landscapes.

In 2009, an opportunity to revisit applications of LiDAR data in a much bigger way presented itself to WVDEP. The Natural Resource Analysis Center (NRAC) at West Virginia University had just inherited a LiDAR scanner and supporting staff from the Canaan Valley Institute, a non-profit organization in Davis, W.Va. concerned with tackling community water issues. Due to the 2003 DMR success with LiDAR, the Agency possessed the necessary in-house insight about the scanner's potential uses. When funding became serendipitously available, DMR contracted NRAC to fly LiDAR over areas of the State with active mining permits and terrain projected to have the most potential for future proposed permits. Unlike most other West Virginia LiDAR datasets, the DMR project was watershed-focused to facilitate future hydrologic modeling. DMR's funding enabled approximately 30 percent of the State's total acreage to be flown making WVDEP's DMR the largest owner of West Virginia LiDAR data.

Even very early in DMR's LiDAR collection project the new LiDAR data proved valuable. In 2011, the new LiDAR data was used by the Technical Applications and Geographic Information Systems (TAGIS) Unit and DMR for an official project. TAGIS staff employed LiDAR in the completion of a viewshed analysis in the vicinity of Blair Mountain in response to a Lands Unsuitable petition that would potentially block access to future mining in that area. DMR staff performed a series of investigations to test the validity of the petition's claims. TAGIS' viewshed analysis determined the distance until visibility was blocked towards features of interest in the area from multiple points along a proposed new permit area. This analysis, assisted by the accuracy of the new LiDAR data and in conjunction with DMR's studies' results, resulted in denial of the petition.

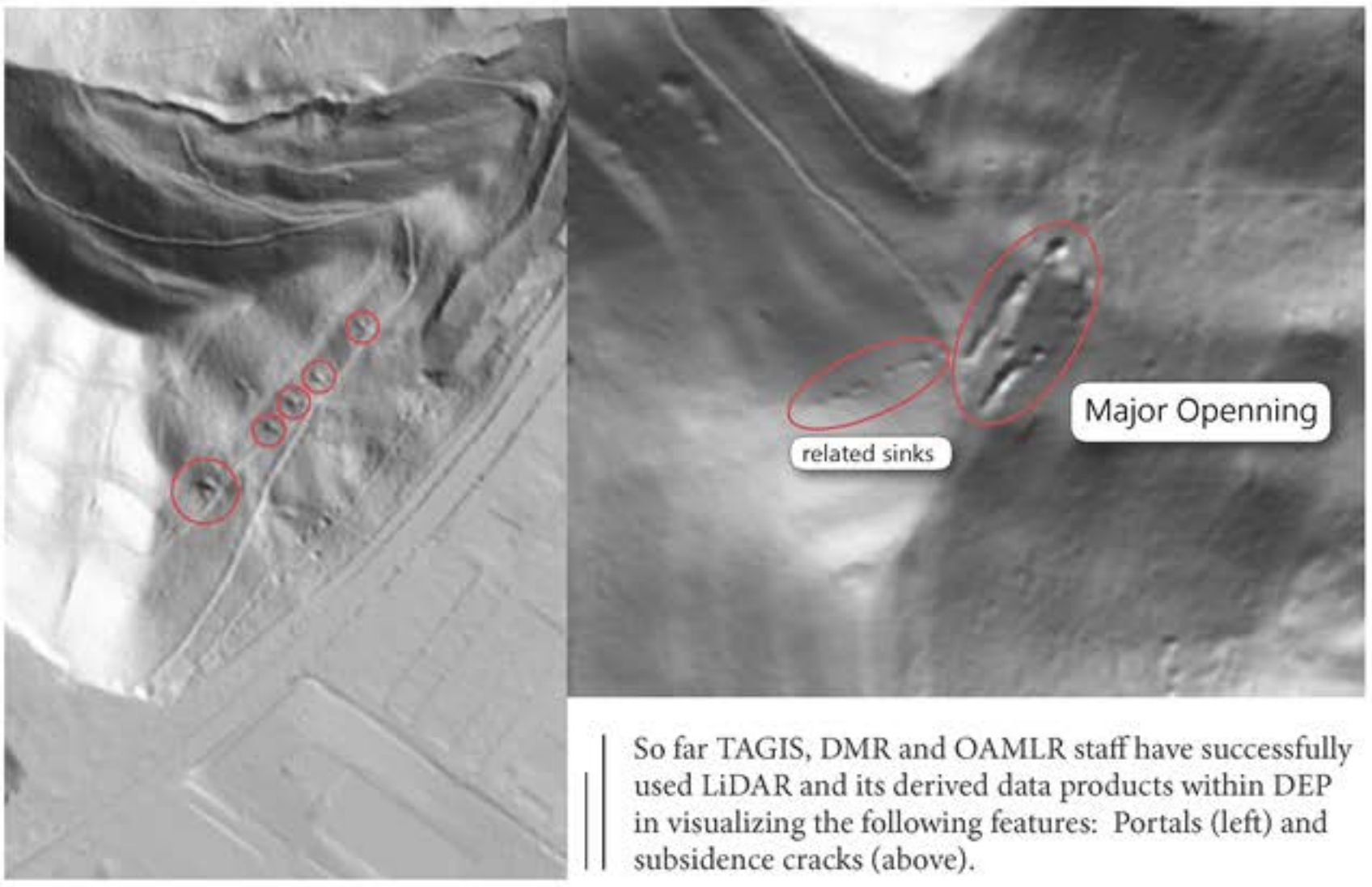
In March of 2012, the TAGIS Unit of WVDEP's Information Technology Office began making available to agency ArcGIS desktop users an "aggregated" hillshade created from LiDAR data. The new data product merged the newest, higher resolution LiDAR owned by WVDEP and LiDAR provided by cooperating partners with the WVSAMB photogrammetrically-derived hillshade dataset from 2003. This aggregated dataset is the best contemporary topographic representation of the entire State in existence. In late March, TAGIS took the project a step further by extending access to the aggregated hillshade to outside users of the Agency's existing Mining Explorer (Data Tools) application (http://tagis.dep.wv.gov/mining/) via a selectable hillshade basemap. These two rollouts represent the first public access to data gathered as part of the WVDEP's DMR LiDAR data acquisition project.

The accuracy of the elevation data partnered with the particularly high point density of the products created from it makes LiDAR a tool not only for future work but also a way to test the precision of previously held Agency records in existing databases. The LiDAR-derived hillshade dataset presents a spectacular data source for the discovery of mining remnants including refuse and valley fills, portals, face ups and entries that were difficult to even impossible to discover previously. In the case of West Virginia's pre-Civil War mine sites, LiDAR is often the best way to detect these features.
The first practical use of the data by Agency staff outside TAGIS Unit, for example, was by the Office of Abandoned Mine Lands and Reclamation (OAMLR). The hillshade was used to mark old portals on the Mallory, W. Va. quadrangle. The location of several portals on the quad was subsequently verified in the field by OAMLR staff. When overlaid onto the older WVSAMB hillshade, none of the portals were visible. However, when placed on the new LiDAR-based hillshade, the locations of the portals from OAMLR's geospatial database could be clearly seen for the first time. Based on the location seen on the hillshade, the

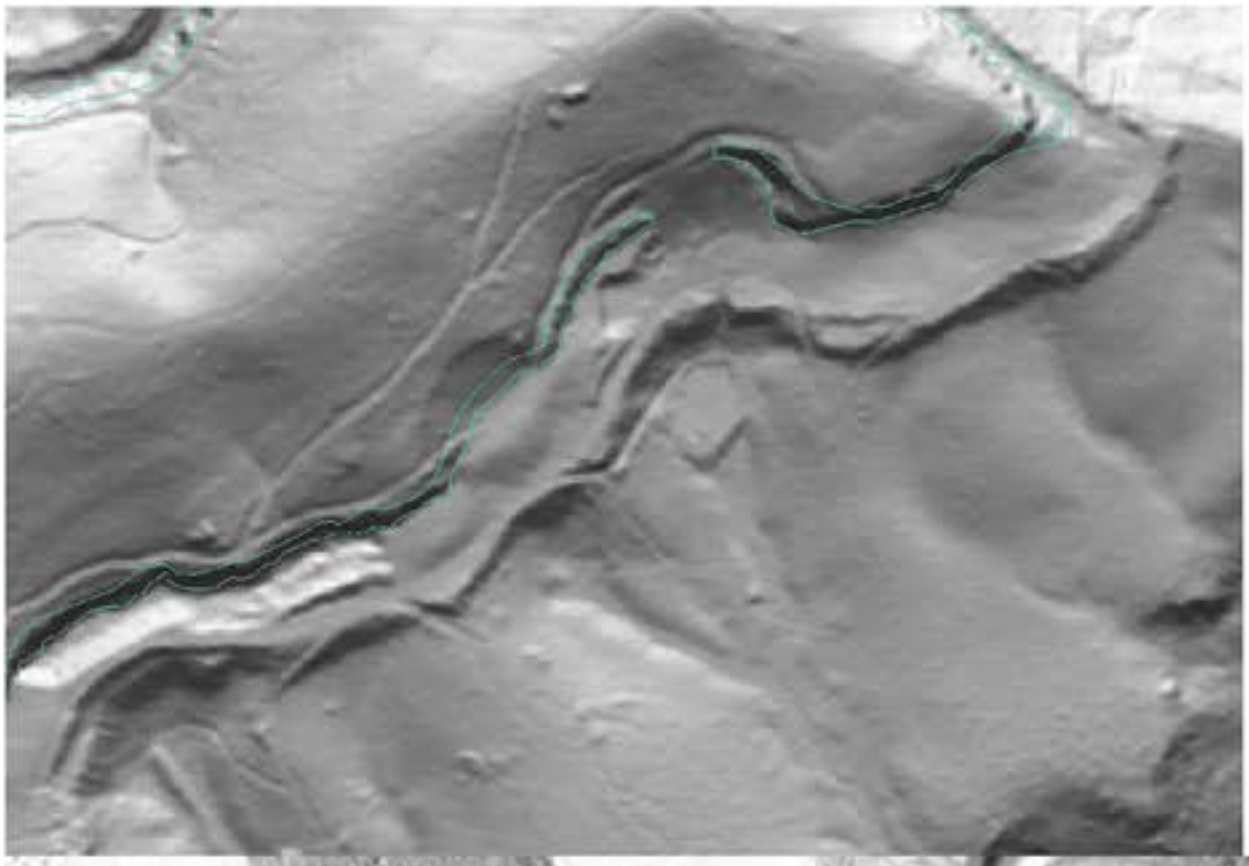
point data in the OAMLR's database that represent the portals are actually plotted too far up slope despite the recent field verification.

Recently, Agency staff found another exemplar use of the new data in AML quite literally in WVDEP's back yard. While viewing the LiDAR hillshade for the area directly adjacent to the WVDEP office in Kanawha City, the team spotted a trail of previously undetected mine openings. Armed with a RICOH GPS digital camera, the team hiked to the perceived location of the AML mine openings to document their findings. Sure enough, the openings from the LiDAR hillshade were there, but even more remarkably, the features were so subtle they proved easier to detect on the hillshade than standing nearly on top of them in the field. After shooting a number of geo-tagged photographs and utilizing ESRI's ArcPAD software to document their locations, staff determined the LiDAR data was accurate to mere feet. It was concluded that the mine was operated by Kanawha City Coal Company some 120 years ago punching into the Winifred coal seam. Without the extraordinary detail in the LiDAR-derived hillshade dataset, these abandoned mine openings would likely have remained undiscovered and unidentified.

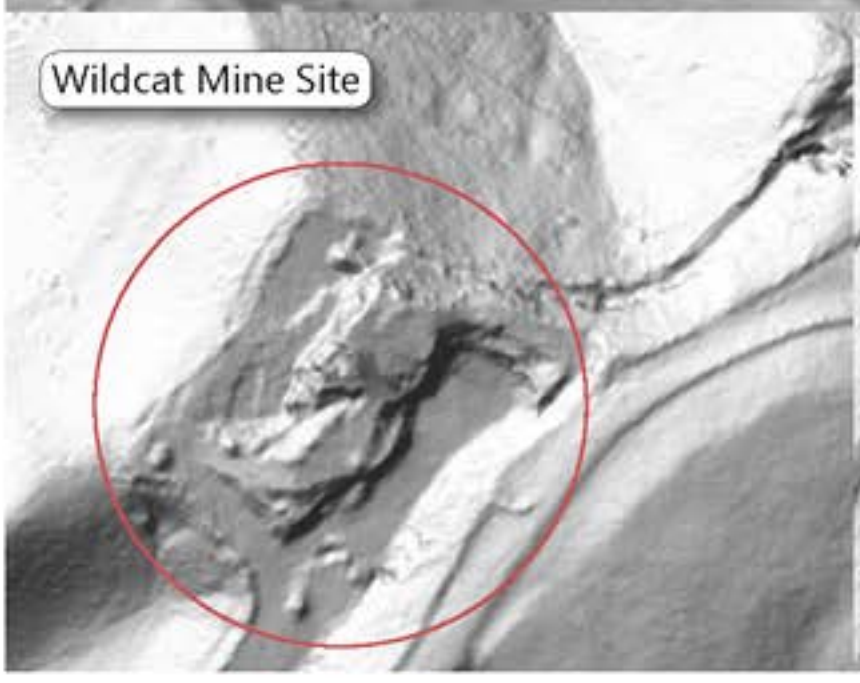
So far TAGIS, DMR and OAMLR staff have successfully used LiDAR and its derived data products within DEP in visualizing the following features:

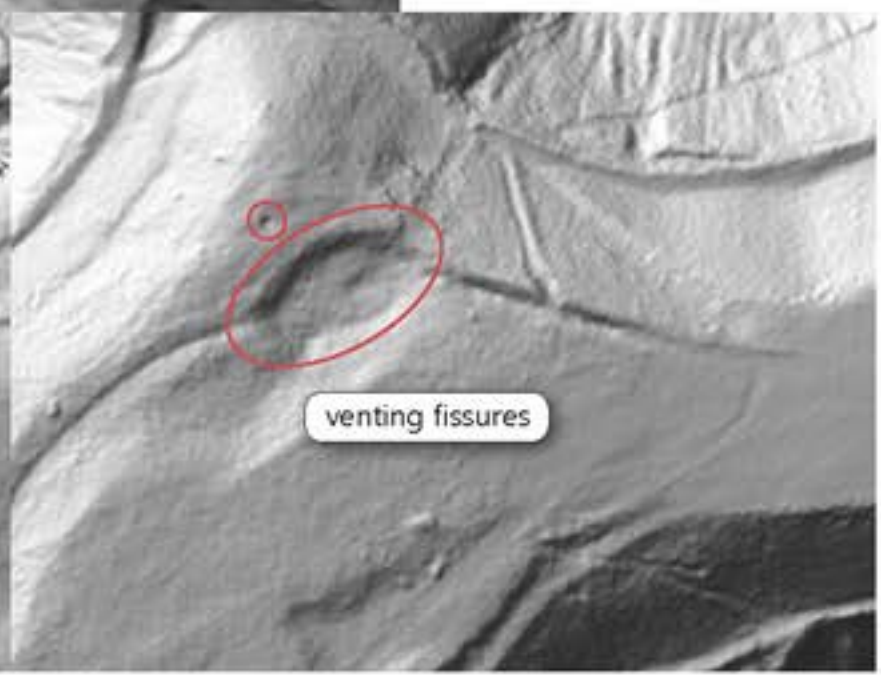


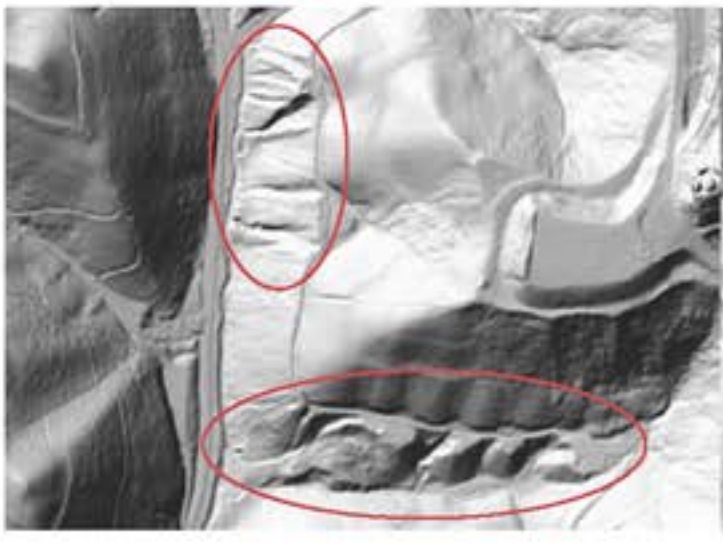
So far TAGIS, DMR and OAMLR staff have successfully used LiDAR and its derived data products within DEP in visualizing the following features: Portals (left) and subsidence cracks (above).

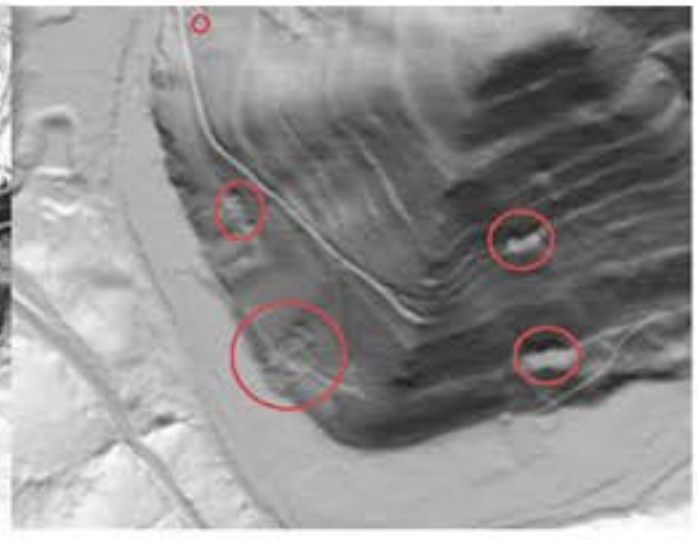


LiDAR data allows professionals to discover dangerous mining aspects such as high walls (left), illegal mining (bottom left) and mine fire vents (bottom right).









LiDAR data has also been used as a tool to detect refuse piles (left) and landslides (right).

LiDAR and its derived data products have great value outside WVDEP too. The ability to distinguish the physical presence of mining relics using hillshade data means scanned mine maps from West Virginia Geological and Economic Surveys can be rescaled and their orientation adjusted to reflect veracity. Improving the precision of these old records inevitably improves the reliability of both Agencies' geospatial archives and increases likelihood of success in dealing with future mine rescues.
Many uses exist for LiDAR's derived data products for non-DEP geospatial users.

The following are anticipated benefits to the larger GIS community in West Virginia:

- Accurately gauged canopy height for forestry professionals
- High-resolution elevation data for use in construction projects:
    - Highway construction and maintenance
    - Routing electric transmission lines
- Precision in farming
- Appropriate selection of new school sites
- Enhanced ecosystem analysis
- Bolstering of natural resources management efforts
- Data support in the study of timely vegetation phenology and health
- Improved disaster response
- Less-invasive archeological detection and study

For the benefit of interested West Virginians, raw binary LiDAR (.LAS) files will be freely accessible through WVView, a local division of the wider AmericaView. AmericaView is a national, incorporated non-profit consortium comprised of scientists, analysts, technicians and educators aligned in an effort to gather and distribute remotely sensed data such as LiDAR. The existence of such an organization and the federal investment and support AmericaView has received since its inception in 2000 is testament to the public worth of this sort of data. After downloading the .LAS files from WVView, specialized software is required to produce derived data. Because not every potential user will have the software or time to create derived data products, WVDEP will, in the near future, provide geospatial professionals desktop access to derived LiDAR datasets via REST-based geoservices from the Agency's public website. The first completed REST accessible data product will be a hillshade, likely available as early as the third quarter of 2012.

The long-term goal of the DMR/TAGIS project is production of LiDAR-derived datasets for multiple watersheds. Most mined terrain or that likely to be mined in the future has now been flown; to fund future LiDAR flights and extend the total area flown in the State, additional funding sources must be identified and utilized. Unless professionals within other fields realize the potential benefits LiDAR-derived data products bring to their work flows, full statewide coverage will remain a pipedream. But because of the myriad of uses possible for LiDAR-derived datasets, the current vision is that LiDAR will eventually be flown statewide. DMR's LiDAR project is scheduled for completion in 2013.